NRL Memorandum Report 2173

NRL Van de Graaff Operation

1 January - 30 June 1970

VAN DE GRAAFF STAFF
EDITED BY K. L. DUNNING

Van de Grauff Branch
Nuclear Physics Division

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NAVAL RESEARCH LABORATORY
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CONTENTS

ABSTRACT

This report is the fifth of a series of semiannual summaries on the use of the 5-MV Van de Graaff accelerator and associated instruments. The period 1 January 1970 to 30 June 1970 is covered. A brief statistical summary is presented, a few important developments concerning the maintenance and improvement of apparatus are discussed, and brief accounts of on-going and recently completed research projects are given.

PROBLEM STATUS

This is an interim report; this work is continuing.

AUTHORIZATION

NRL Problem H01-42 Project RR 002-09-41-5676
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NRL Van de Graaff Operation

1 January - 30 June 1970

I. INTRODUCTION

This is the fifth of a series of reports on the operation and use of the 5-MV Van de Graaff accelerator and associated instruments. This facility serves scientists on the staff of the Van de Graaff Branch, those from other parts of NRL, other government agencies, and universities. Some investigations are entirely within the Branch; some are carried out collaboratively between Branch personnel and others; some are carried on by "users" without close collaboration but with advice and assistance from the Branch Staff. During the period covered by this report, problems in basic nuclear physics have been phased out; however, data from past experimental work not yet published will be published. New work undertaken by the Branch will be in the areas of ion implantation, materials analysis, channeling of ions in crystals, and the application of nuclear and accelerator techniques to problems of Naval relevance.

The Van de Graaff Branch organization as of 30 June 1970 was as follows:

Van de Graaff Branch

7670	K. Dunning, Head M. McDonough (Sec.)
7671	P. Malmberg C. Kennedy W. Young
7672	A. Knudson K. Burgart M. Rardin F. Young[1]

[1] Also with U. of Maryland, College Park, Md.

II. VAN DE GRAAFF OPERATIONS — 1 January - 30 June 1970 (C. Kennedy)

A. BEAM/MAINTENANCE FRACTION

		Hours	Percent of Total Hours
1.	Belt-on time (Users)	489.2	75.2
2.	Belt-on time (Maintenance)...	25.7	3.9
3.	Other Accelerator Maintenance and Improvements.....	136.0	20.9
	Total Time (1 + 2 + 3)	650.9	100.0

B. ACCELERATOR USE

		Hours	Percent of Users Belt-on Time
1.	Branch staff and collaborators	434.3	88.8
2.	J. A. Blodgett (SSD)	7.3	1.5
3.	C. M. Williams (MET)	47.6	9.7
	Users Total	489.2	100.0

III. IMPROVEMENTS AND MAINTENANCE

The following comments briefly describe some of the more important improvement and maintenance activities for the period of this report.

A. Computer Servo System (C.A. Kennedy and M.C. Rardin)

Control circuits for driving stepping motors have been installed in the servo system which will be used for computer control of experimental apparatus. This addition to the servo system provides for operation of up to 32 stepping motors. In addition, it is possible to select any one of seven clutches for each motor so equipped. Motor selection, direction, speed of operation, and number of steps are under direct control of the computer. Manual override capability is available on any motor for which this feature is required.

Test programs have been written in order to test the servo system stepping motor control and stepping motor operation. An operational subroutine has been written to convert the 4221 BCD code of the digital voltmeter to the 8421 BCD code which can be readily handled by the computer.

B. Scaler Input Circuits (C.A. Kennedy)

A new panel for the data acquisition system has been completed and installed to provide for easy selection of scaler input polarity and threshold. This new unit eliminates the need for wiring changes when signal input polarity reversal is required, and eliminates the awkward signal threshold adjustments behind the panel.

C. Computer-Controlled Pulser Voltage Source (C.A. Kennedy)

A digital-to-analog converter (DAC) with reference power supply and analog output amplifiers has been installed as part of the data acquisition system. This circuit provides a source voltage adjustable from 0 to plus 5 volts in increments with 10 bit resolution (i.e., 1024 increments). The analog output is available as source voltage for relay pulsers. Any voltage in the range can be selected by proper setting of a buffer register associated with the DAC (on computer command). This system has been checked out by means of a suitable test program written for the computer.

A subroutine has also been written for the computer-controlled pulser voltage source. This program provides for selection of the present 10-bit or a 15-bit DAC which is on order. The voltage can be incremented any desired amount within the resolution of the DAC selected. An updated version will be provided to permit selection of the starting voltage or base line.

D. Panel Meter Illumination (E.J. Kirk)

Wiring and mechanical assemblies have been completed and installed on all 3-inch meters on the Van de Graaff console. This change provides for scale illumination on these meters under the control of a console switch. Scale illumination is helpful in increasing visiblity of the panel meters when room lighting is reduced.

E. Ion Source Test Bench (W.H. Lucke,* K.Q. Burgart, and M.C. Rardin)

An attempt was made to increase the $^{11}B^{+}$ beam current using an arrangement described by S. Bashkin. A BCl_3 bottle and a helium bottle were manifolded to the control leak valve, the idea being that after a short period of operation with pure BCl_3 this bottle would be shut off and the helium bottle opened. Thereafter, helium would act as a carrier gas for the residual BCl_3. Initial trials yielded no increase in the $^{11}B^{+}$ beam current. At this point, the controlled-leak valve failed. Since it had been in use for over a year with the corrosive BCl_3, this was considered to be the result of natural wear and tear and it was simply replaced. The subsequent failure of this valve and trouble with the vacuum system convinced us that the system had been heavily contaminated by water vapor with consequent corrosion by HCl. The high-voltage end of the system (including all lenses) was taken apart, cleaned and reassembled. Vacuum pumps, leak valve and storage bottles were replaced. So far there has been no further trouble.

Correspondence with Bashkin indicated his complete confidence in his method and the assurance that our system did not differ substantially from his. In further attempts, increases by a factor of 4 or 5 (from [illegible] to [illegible] nano-amps to 120 na) in $^{11}B^{+}$ beams were achieved. However, when

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the $^{11}B^{+}$ peak was scanned, frequently a shoulder or double peak was found. It was not initially clear whether this was due to aberrations in the lens system or the presence of some foreign ion species ($^{35}Cl^{+++}$ would fall in this vicinity) due to discharge conditions in the R.F. bottle. However, when hydrogen was substituted for helium, a scan of the $^{1}H^{+}$, $^{1}H_{2}^{+}$ and $^{4}He^{+}$ peaks all showed the same double peaks, indicating that it is caused by aberration. Preliminary results of further study show that this effect can be eliminated by keeping the pressure in the R.F. bottle at 10 microns or less and keeping the voltage on the low energy einzel lens high. Both of these factors can have deleterious effects; in particular, high "focus" voltage causes a severe reduction in beam current.

F. Accelerator Tube Construction (W.S. Young)

Throughout this period work has been progressing on the reconstruction of another acceleration tube for the Van de Graaff. The first section is completed, tested, and in storage. The second section is completed and awaiting test. The third section has been disassembled, the electrodes are polished, the porcelains have been sand-blasted and are awaiting cleaning, coating, assembling, and testing. This work is going ahead as time permits.

G. Servo Terminal Power Supply Assembly (M.C. Rardin and C.A. Kennedy)

An assembly has been completed to provide voltages for operation of servo-terminal circuits and displays for the data acquisition system. One supply provides power to operate the relay matrix used for digital voltmeter input selection. A second power supply provides the necessary voltages to operate servo-terminal status indicators. A third supply provides a well-regulated source voltage for the position indicator potentiometers.

H. Beam Analyzing Magnet Coils (K.Q. Burgart)

During the past year, two of the sixteen coils on the beam analyzing magnet developed shorts to ground; they were disconnected awaiting later repair. Repair requires disassembly of the magnet and was begun during the latter part of June.

I. Two-Axis Goniometer for Channeling Studies (A.R. Knudson, and W.S. Young)

Plans for a goniometer were obtained from Dr. L. Feldman of the Bell Telephone Laboratories. These plans were modified to adapt this goniometer to our 18" scattering chamber and also to enlarge the area of the sample holder so that the sample can be viewed by a detector over a larger angular range. This goniometer provides for 360° rotation of the crystal sample about a vertical axis and also about a horizontal axis perpendicular to a face of the crystal. The sample holder spool is insulated from the remainder of the goniometer so that incident beam current may be measured when the beam stops in the sample. The goniometer is presently under construction.

IV. RESEARCH HIGHLIGHTS

These notes indicate progress on those investigations carried on at the 5-MV Van de Graaff in which members of the Van de Graaff staff made a major contribution. Those projects in which staff members participated in a minor way are treated in the next section.

A. Irradiation of Gallium Phosphide with an Argon Beam (J.E. Davey,* T. Pankey,* P.R. Malmberg, W.H. Lucke†)

Earlier work by Pankey and Davey had shown that the optical absorbtion edge of gallium phosphide (GaP) could be shifted to the infra-red by neutron irradiation. It was desired to see if similar effects could be obtained with charged particle irradiation. Therefore, samples of GaP were irradiated with scanned monoenergetic beams of 1.5- and 3.0-MeV argon ions.

The typical sample was a thin film of GaP on a quartz or sapphire substrate. The films were deposited from a vapor phase and annealed as necessary to be transparent (but yellow) to the eye, indicating an absorbtion edge in the visible spectrum. Masks were used during irradiations so as to limit area irradiated; typically, a 1/8" square hole was used. Flux and argon energy could be therefore varied on a single sample so that comparisons of effects of irradiations could be made without concern for variation between samples.

The first trial, with an integrated flux of 10^{15} argon atoms per square centimeter at 3 MeV, gave a pronounced darkening of the samples used. Trials were made with different samples, different argon energies, and various fluxes. The general effect was the same although some samples appeared more sensitive to darkening than others. Heavily darkened samples appeared metallic to the eyes. Examination of the optical absorption spectra showed a shift of the absorbtion edge to the infra-red; quite comparable to the results for neutron irradiation.

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*Electronics Division

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B. Neutron Spectrometer Development (P.R. Malmberg)

The computer program NFLD (for uNFoLD spectrum) was debugged. This program is used to obtain the neutron spectrum from a given pulse height distribution obtained with an organic scintillator. It is based upon the program coded for the CDC-3800 computer by M.E. Toms and D.W. Jones of the Linac Branch.

A monoenergetic neutron beam should ideally yield a single peak on an unfolded spectrum. However, it is found that the spectra obtained by use of these programs show small satellite peaks at lower energies. In order to examine these satellite peaks as a function of energy, a set of runs was made using a 1" x 1" stilbene crystal with monoenergetic neutrons of 3.67-, 4.0-, 5.0-, 6.3-, 7.0-, 7.58-, 8.0-, and 8.1-MeV from the $D(d,n)He^3$ reaction. The pulse height spectra obtained were unfolded by the program NFLD. Appreciable variations in the satellite structure as a function of incident neutron energy were noted.

C. Cosmic Ray Balloon Flight Data Processing (C.A. Kennedy and R.C. Noggle*)

Recent balloon flights by the Laboratory for Cosmic Ray Physics produced several reels of magnetic tape telemetry data. The data was not in a form that could be processed using digital computer methods. The SEL 840A computer with the associated peripheral scalers and interfacing equipment provided a means of converting the data into a form usable in digital computation.

Additional logic and gating circuits were added to the system in order to meet the requirements of the source data. A program was written to process the data and transfer it to magnetic tape in digital format suitable for use on the CDC 3800 computer.

After computation and testing of the hardware and program, the telemeting data were reduced and transferred to magnetic tape in computer format for final analysis and processing.

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*Laboratory for Cosmic Ray Physics

D. Low Energy Implantation of Hydrogen into Steel (C.D. Beachem,* T.C. Lupton,* W.H. Lucke,† and P.R. Malmberg)

The embrittlement of high strength steels by exposure to hydrogen is a vexing problem about which little is understood. Cracks develop and propagate at stresses far below normal values. In an attempt to clarify the problem, experiments were designed to permit electron transmission microscopy at magnifications of up to 200,000 x of quenched and tempered foils of AISI 410 stainless steel. At these high magnifications, the microstructural details of this steel are clearly discernible and gross hydrogen damage in the form of cracks or voids would easily be seen.

The problem of introducing hydrogen in these fragile, thin (thickness a few hundred angstroms) foils and preserving the cleanliness requisite for such high magnifications suggested ion implantation as the best solution. Accordingly, two samples were implanted with 2.5-keV hydrogen ions to doses of 3×10^{15} and 5×10^{16} ions/cm^2 (which correspond roughly to concentrations of 3×10^{19} and 5×10^{20} ions/cm^3).

The results were negative; nothing definitely abnormal was observed upon subsequent microscopic examination. So far, no reasonable explanation for this has been adduced. Attempts to introduce hydrogen by an electrolytic process are being made. It is possible that, if it is determined what the microscope should show, a return will be made to ion implantations.

E. Ion Implantation of Barium $BaTiO_3$ (B.K. Molnar,** P.R. Malmberg, W.H. Lucke†

Electron and x-ray diffraction studies of small crystallites of $BaTiO_3$ have demonstrated the existence of a surface layer substantially different from the interior of the crystal. Several experimental findings have indicated the existence of a similar layer on large single "butterfly" crystals. This layer, reported as being between 0.01 and 10 μm thick, influences many of the important properties of the crystal. To date, a clear explanation of the formation and character of the surface layer has not been achieved.

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Since ion implantation also forms a surface layer, it affords a unique method of creating thin surface layers and studying their effect on the volume properties of ferro-electric crystals.

Accordingly, several single crystals of $BaTiO_3$ were implanted with 0.5-MeV $^1H^+$ ions (achieved by accelerating $^1H_2^+$ ions to 1 MeV) to doses of 2×10^{13}, 5×10^{14}, 2×10^{15} and 4×10^{15} ions/cm^2. Microscopic examination showed no visible change in the crystal surfaces. Rather small changes in the hysteresis loop were observed.

The experiment was repeated with 1-MeV $^{40}A^+$ ions implanted to surface densities of 5×10^{13} and 5×10^{14} ions/cm^2. At this energy, the range of the ions is estimated as about 0.5 μm. Four of the crystals were implanted on both sides to the higher dose. Microscopic examination showed that for the 5×10^{14}/cm^2 implants there was a high density of 90° domains on the exposed surface, and that these twinned areas stopped very sharply at the edge of the exposed region (part of the crystal was shielded during implantation).

Since this is known to be the way that $BaTiO_3$ behaves in minimizing strain energy, it is very probable that the implantation caused an expansion of the surface layer.

The effects on the hysteresis loops were very marked, distorting the loops to such an extent that it was frequently impossible to describe it in terms of a definite coercive field or a saturation polarization value. In the case of the crystals implanted on both sides, it is sometimes possible to speak of a built in field, i.e., the (distorted) loop was displaced along the field axis away from the origin.

Future plans are to investigate more fully the nature of the damage caused, the effects of annealing, and of different ions.

F. Analysis of Metal Surfaces for Residual Grains of Polishing Compounds (J.W. Butler, E.A. Wolicki*, M. Bernett**)

In cooperation with the Laboratory for Chemical Physics, we have used nuclear techniques to measure the amounts of residual polishing compound left on a number of metal surfaces after polishing. When γ-alumina (.3 μ average particle size) was used as the abrasive, the

*Nuclear Physics Division Staff
**Laboratory for Chemical Physics

analysis was made by means of the 992-keV resonance in the $^{27}Al(p,\gamma)^{28}Si$ reaction. When magnesium oxide was used as the abrasive, the analysis was made by means of the 1546-keV resonance in the $^{26}Mg(p,\gamma)^{27}Al$ reaction.

The polished surface (protected from condensable vacuum-system contaminants by an enclosing tube at liquid-nitrogen temperature) was bombarded by the molecular H_2^+ beam (used for reasons of convenient accelerator operation) from the Van de Graaff accelerator. The emitted gamma rays were detected by means of a 3-inch diam. by 3-inch NaI(Tl) crystal and a multichannel pulse-height analyzer. The crystal was at 90° with respect to the proton beam, and the distance from the beam (or center of the target) to the face of the crystal was about 2 cm.

Table F1 lists the results (including the approximate depths of penetration of the grains into the metals) for alumina. Figures F1-F3 illustrate the resonance curves for a "surface" layer of residual grains, a moderate-depth layer, and a thick layer, respectively.

Table F2 lists the results for magnesium oxide. For the lower-Z metals, the magnesium could not be detected because of the background yield from the metal itself (a higher bombarding energy was used for magnesium than for aluminum).

Table F1. Amounts of aluminum per unit area left on the various samples. In addition, the depths of penetration of the polishing grains are indicated. Uncertainties are about 10-20 per cent.

Metal	Amount $\mu gm/cm^2$	Depth of Penetration mg/cm^2
Cr	0.020	0.16
W	0.030	0.25
Mo	0.035	0.3
Ag	0.085	0.14
Ni	0.13	0.4
Zn	0.14	<0.07
Cd	0.14	<0.07
Zr	0.27	<0.07
Nb	0.35	<0.07
Sn	0.48	0.20
Au	0.85	0.27
Cu	0.92	0.7

Table F2. Amounts of magnesium per unit area left on the various samples. Uncertainties are about 20-50 per cent.

Metal	Amount μ gm/cm^2
Mo	<0.01
Zr	0.01
W	0.02
Cd	0.02
Nb	0.06
Au	0.20
Ag	0.24

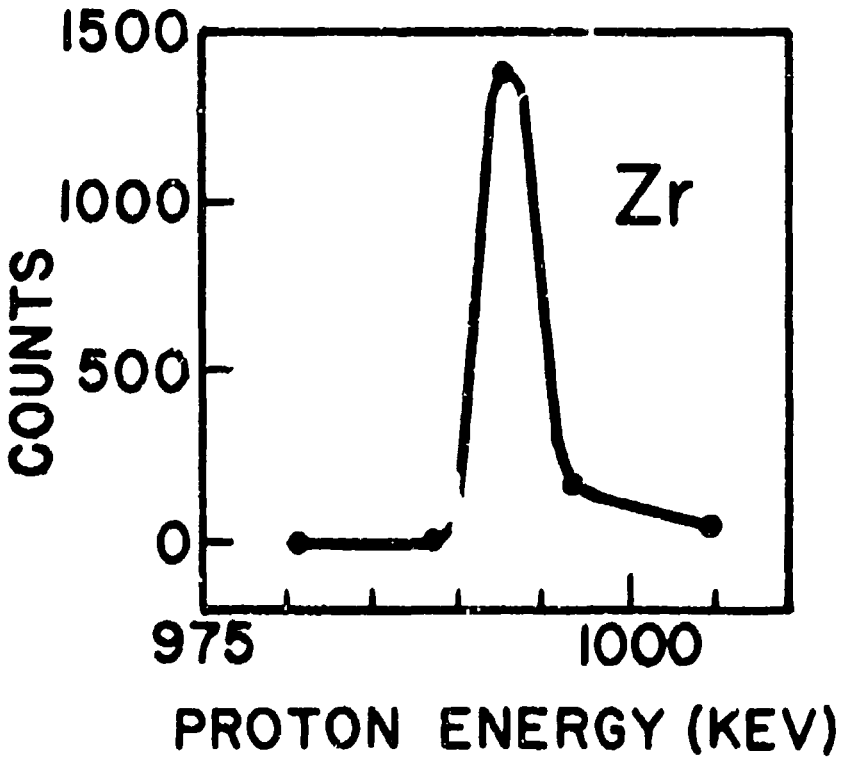

Fig. F1 - Yield curve of gamma-ray counts vs. incident energy for a "surface" layer of polishing compound grains. The polished material is zirconium.

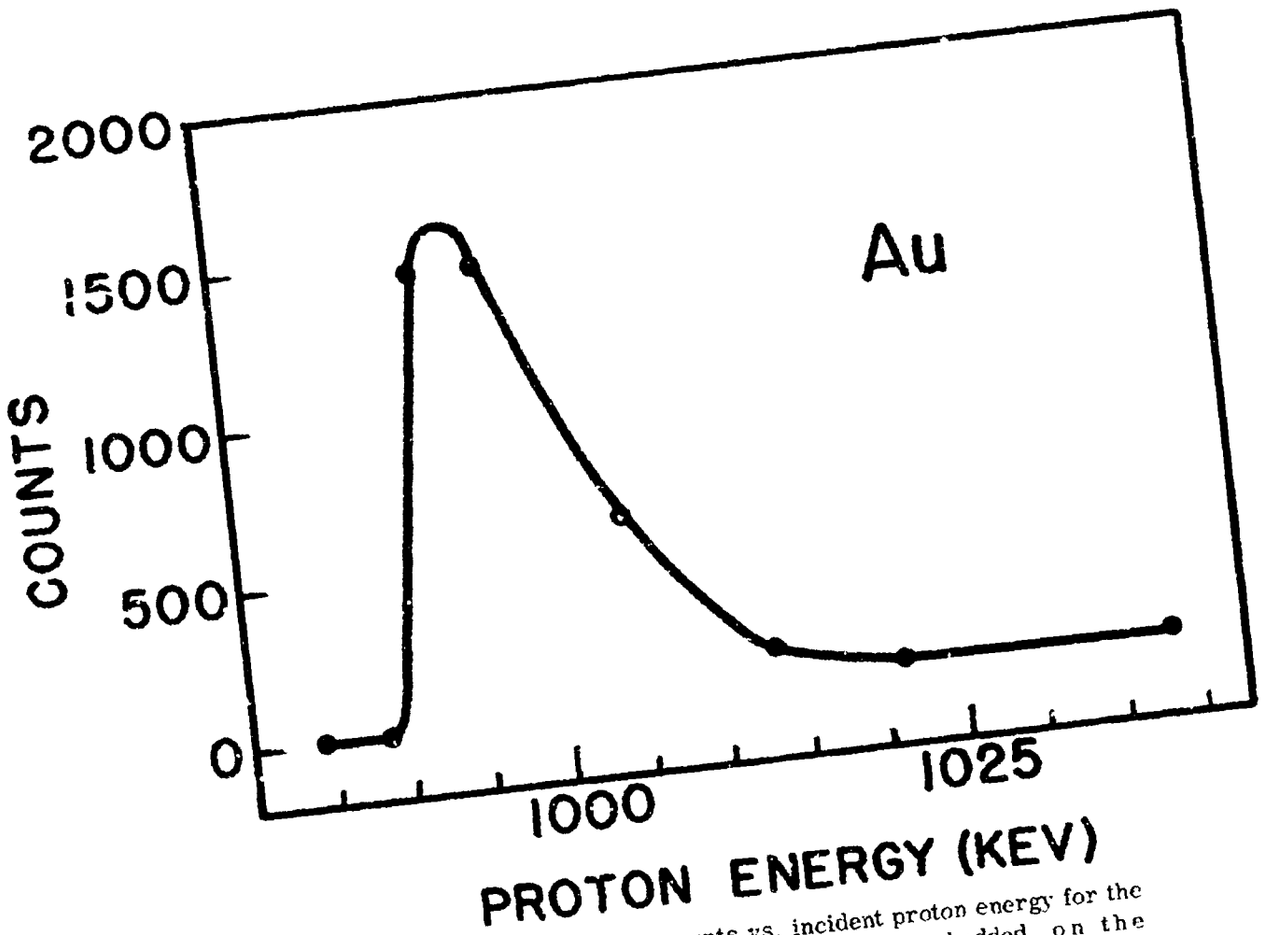

Fig. F2 - Yield curve of gamma-ray counts vs. incident proton energy for the residual polishing compound on gold. Here the grains are embedded, on the average, to intermediate depths in the gold.

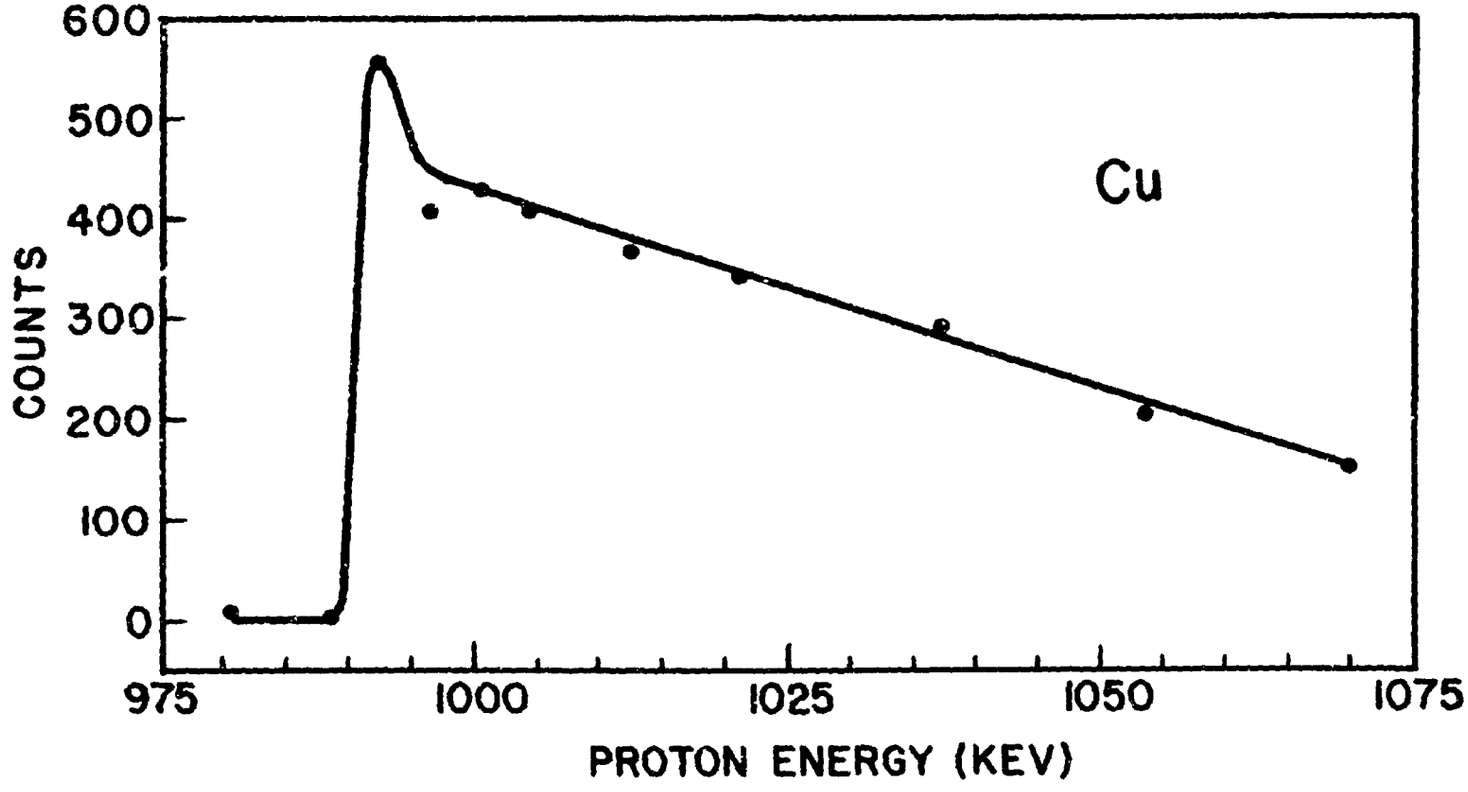

Fig. F3 - Yield curve of gamma-ray counts vs. incident proton energy for the residual polishing compound on copper. Here the grains are embedded, on the average, relatively deeper in the copper.

G. ^{9}Be(^{3}He, ^{6}Li)^{6}Li Reaction (F.C. Young, A.R. Knudson, and R.O. Mead[x])

The results of experimental studies of the ^{9}Be(^{3}He, ^{6}Li)^{6}Li reaction have been previously reported in NRL Memorandum Report 1984. The sharp forward peaking of angular distributions taken at incident ^{3}He energies of 7.0 and 8.0 MeV, as well as the smooth variation of excitation curves taken at 20° (lab) and 90° (c.m.) suggest a direct reaction mechanism. The FORTRAN program JULIE has been adapted to the specialized situation occuring in this reaction, namely, the presence of two identical nuclei in the exit channel. Distorted wave calculations have been carried out using optical potentials derived from the measurements of Earwaker[1] for ^{3}He elastic scattering on ^{9}Be at 8.0 MeV and the measurements of Pinnsoneault and Blair[2] for ^{6}Li elastic scattering on ^{6}Li at 7.0 MeV. A direct pick-up mechanism has been assumed and zero range DWBA calculations performed. ^{9}Be was assumed to consist of a ^{6}Li cluster plus a triton cluster. Relative orbital angular momentum values of 1 and 3 are allowed by angular momentum and parity conservation, but $\ell = 3$ is found to give a poor fit to the data. For $\ell = 1$, both $j = \frac{1}{2}$ and 3/2 are allowed, but as is shown in Fig. G1, only $j = 3/2$ gives a reasonable fit to the data. Coherent admixtures of $j = \frac{1}{2}$ and 3/2 were also tried but no improvement resulted. The quality of the agreement between theory and experiment seems to definitely indicate that this reaction is proceeding by a direct pick-up mechanism. Further refinements in the theory, such as treating the transferred nucleons individually instead of as a cluster, might reduce the remaining differences between the calculated and experimental angular distributions.

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[x]University of Maryland

[1]Nucl. Phys. A91, 96 (1967)

[2]Phys. Rev. 141, 61 (1966)

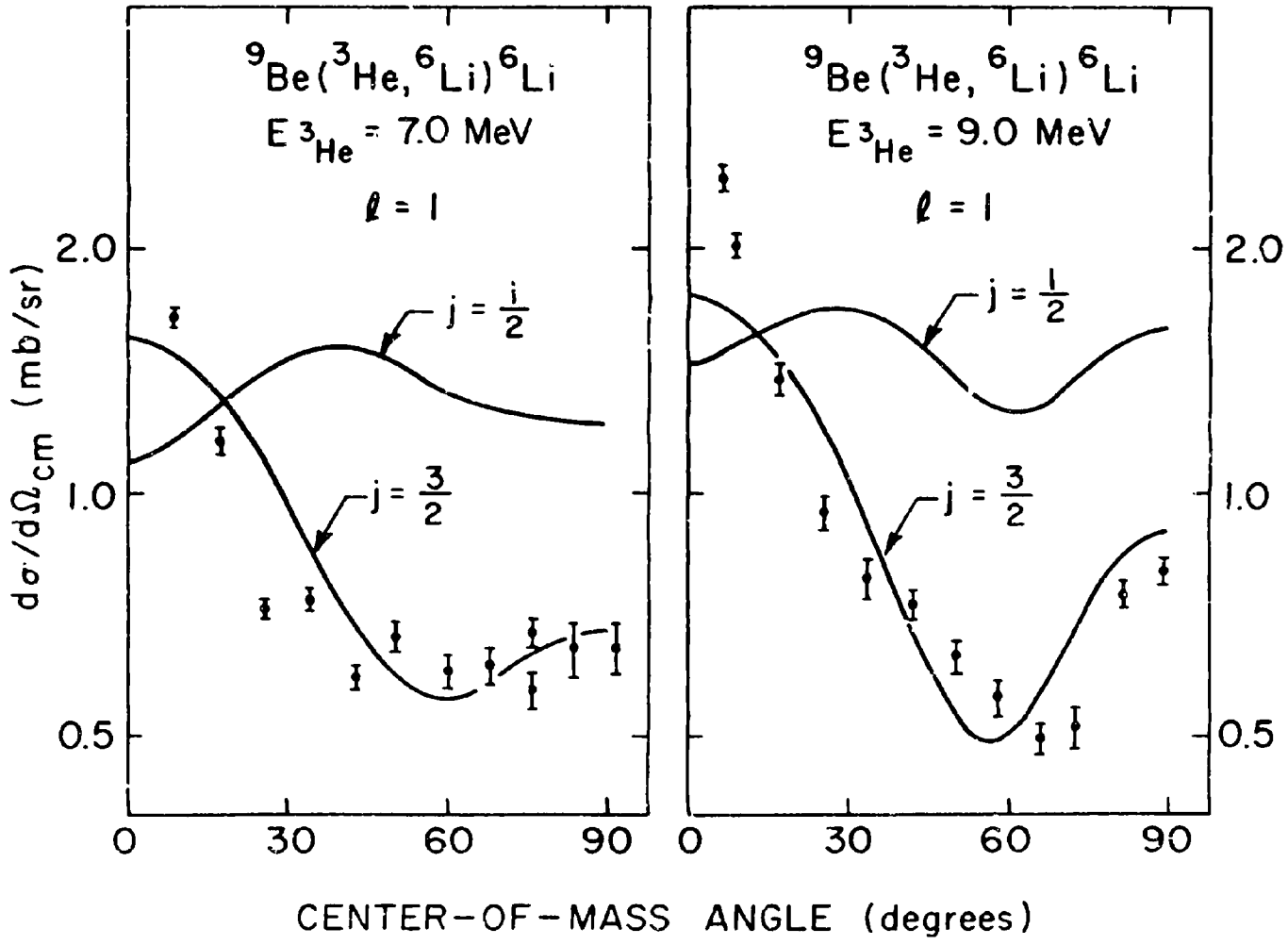

Fig. G1 - The results of DWBA calculations for the pick-up of a triton cluster from ^{9}Be are shown as solid curves. together with experimental data for the $^{9}Be(^{3}He, ^{6}Li)^{6}Li$ reaction.

H. Detection of Chorine on Aluminum by Charged-Particle Induced Reactions (A.R. Knudson and K.L. Dunning)

In connection with corrosion studies being carried on in the Metallurgy Division, it is important to be able to measure small quantities of Cl on Al surfaces. Various charged particle beams from the 5-MV Van de Graaff were used to study both prompt and delayed radiations in an effort to obtain maximum sensitivity and convenience in the detection of Cl. These studies are described briefly below. The samples used in these measurements were produced by evaporating $BaCl_2$ or NaCl onto Al foil.

1. Detection of γ Radioactivity

Natural chlorine consists of 75.5% ^{35}Cl and 24.5% ^{37}Cl. The $^{37}Cl(d,p)^{38}Cl$ reaction was used to produce ^{38}Cl which decays with a 37.2-minute half life as shown by the decay scheme in Fig. H1. After bombardment for about an hour with 50 nanoamperes of 5.0-MeV deuterons, and a delay of about 15 minutes to allow the intense ^{28}Al activity (2.3 min. half-life) to die away, counting was begun with a 5" diam. x 5" well-type NaI crystal. Unfortunately, Mn and Ga impurities were present in the Al foil which interfered with the detection of the Cl γ-rays.

Measurements were also made using a 30 cm^3 Ge(Li) detector. The spectrum obtained is shown in Fig. H2. The high resolution of the Ge(Li) detector readily allows the ^{38}Cl γ-rays to be distinguished from those produced by the activation of Al, Na, Mn, and Ga. This target contained [illegible] $\mu gm/cm^2$ of Cl. It is estimated that 0.1 $\mu gm/cm^2$ of Cl would just be detectable.

Since the ^{38}Cl γ-decay mode is primarily a cascade process, it was anticipated that detecting the two γ-rays in coincidence would considerably reduce the interference from those other activities induced in the Cl and Al which decay by emission of a single γ-ray. The two-parameter mode of data taking also effectively enhances the resolution since, for example, a 1.64-MeV γ in coincidence with a 2.17-MeV γ will show up in a much different region of a two-parameter space than (to choose an illustration) a 1.70-MeV γ in coincidence with a .45-MeV γ, whereas in the NaI singles spectrum, the 1.64 and the 1.70-MeV γ-rays would not be resolved. The spectrum obtained, requiring coincidence between a 5" x 5" and a 3" x 3"

NaI detector, is shown in Fig. H3. Two "islands" due to the presence of Cl are indicated on the figure. Most of the remaining structure is due to γ-rays from the decay of ^{24}Na. This target contained 4 $\mu gm/cm^2$ of Cl, but the Cl "islands" have been seen with as little as .2 $\mu gm/cm^2$.

2. Detection of β Radioactivity

High energy electrons are also emitted in the decay of ^{38}Cl. Electron spectra were observed with a 1" diameter by 1-1/4" long piece of NE-102 plastic scintillator optically coupled to a 6199 photomultiplier tube. In Fig. H4, the lower curve is the spectrum from an irradiated Al foil and, as expected, contains very few high energy electrons. The upper curve is the spectrum with 40 $\mu gm/cm^2$ of Cl on the Al foil. It was estimated that about 0.1 $\mu gm/cm^2$ of Cl could be detected by the technique, but the lack of well-defined structure characterizing the elements contributing to the spectrum, makes it difficult to be sure that in a given sample some unknown contaminant is not contributing to the high energy portion of the spectrum. This can be ascertained by determining the half-life of the high energy electrons, but to do this accurately probably requires a Cl surface density of the order of 10 $\mu gm/cm^2$.

3. Detection of Elastically Scattered α-Particles

Detection of elastically scattered α-particles was found to be at least as sensitive as any of the methods previously described and was faster and more convenient than the other methods. Fig. H5 shows the spectrum obtained using 3.0 MeV α-particles scattered at an angle of 150° from a target containing 0.1 $\mu gm/cm^2$ of Cl. The continuum is due to scattering from the Al substrate. The righthand portion has been multiplied by 20 and replotted to show the two peaks attributable to α scattering from ^{35}Cl and ^{37}Cl.

In conclusion, the α-particle elastic scattering is the preferred technique for the detection of thin Cl films on Al. However, if the Cl were not on the surface or if the Cl were present as a surface film on a heavier substrate material, either the use of a Ge(Li) detector to observe the singles γ-radioactivity or the use of coincidence techniques to observe the γ spectrum would be useful methods to apply.

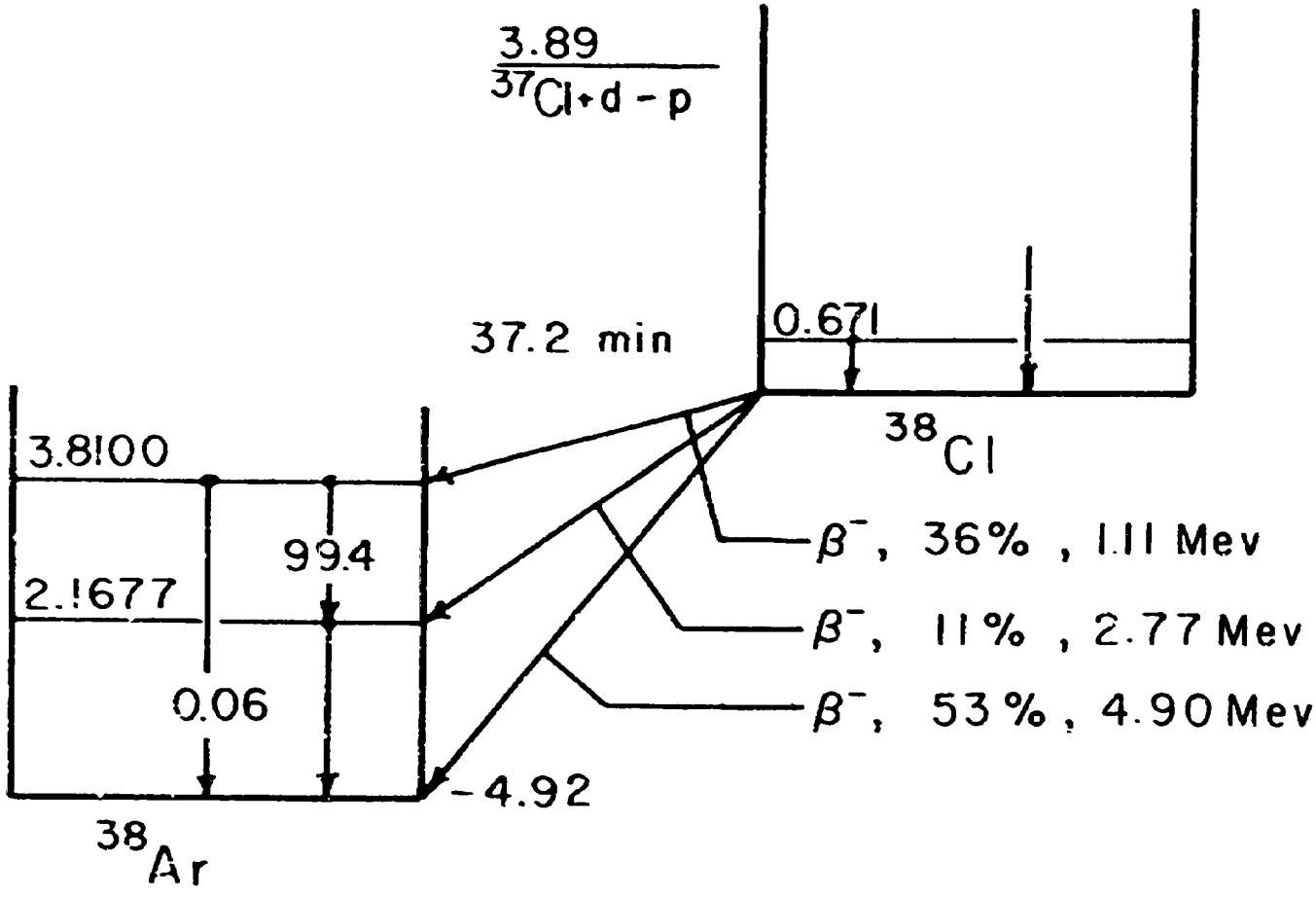

Fig. H1 - Decay scheme of ^{38}Cl.

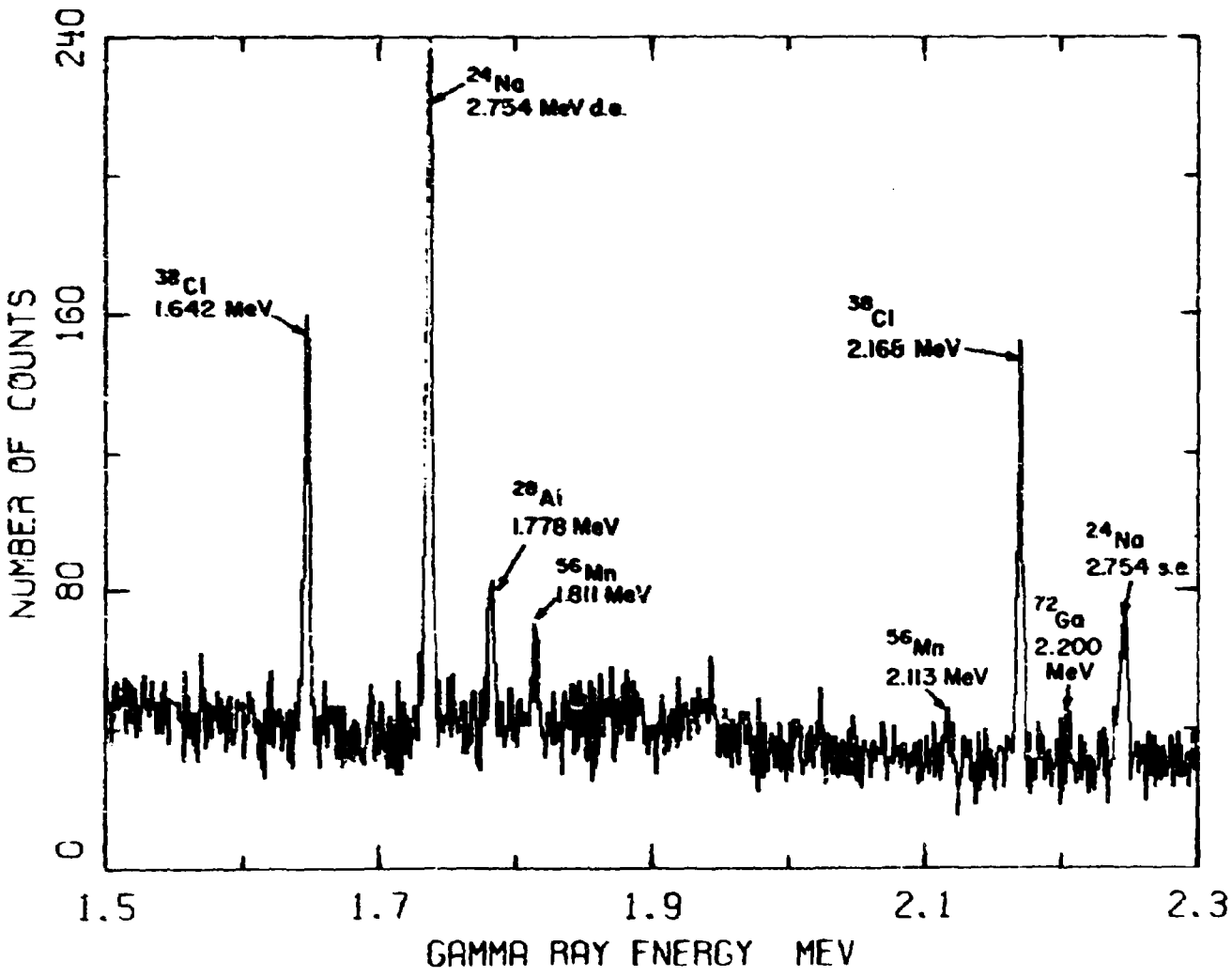

Fig. H2 - γ-ray spectrum obtained with a GE(Li) detector from a target containing 0.8 μgm/cm^2 Cl on Al, after irradiation with 5.0-MeV deuterons. s.e. indicates a single escape peak and d.e. a double escape peak.

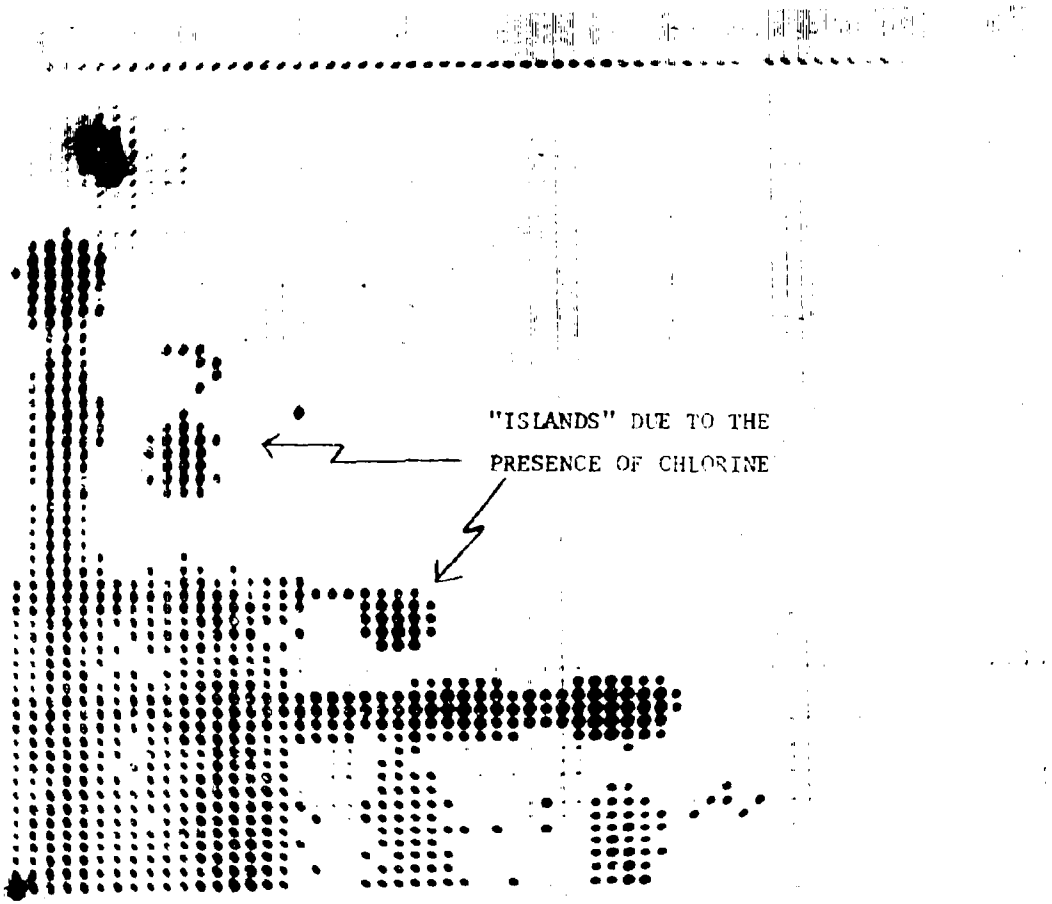

Fig. H3 - This is a display of a two parameter spectrum obtained requiring coincidence between a 3 in. × 3 in. and a 5 in. × 5 in. NaI crystal. γ-ray energy in the 5 in. × 5 in. NaI crystal is presented along the x axis, while γ-ray energy in the 3 in. × 3 in. NaI crystal is present along the y axis. Each channel that contains more than 32 counts is intensified in the display.

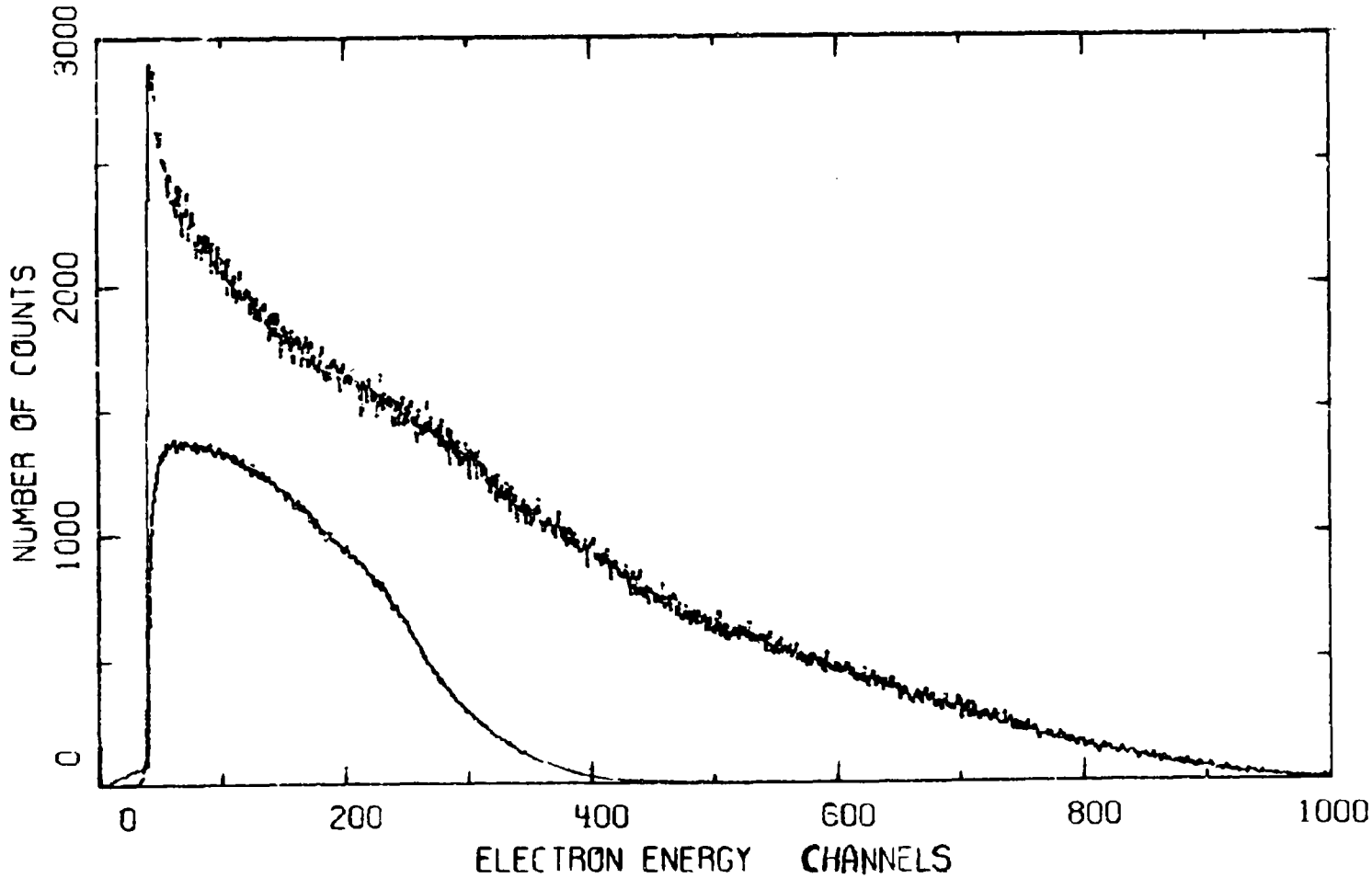

Fig. H4 – Electron spectra from Al foil (lower curve) and Al foil with 40 μgm/cm^2 of Cl on surface (upper curve) after irradiation with 5.0-MeV deuterons.

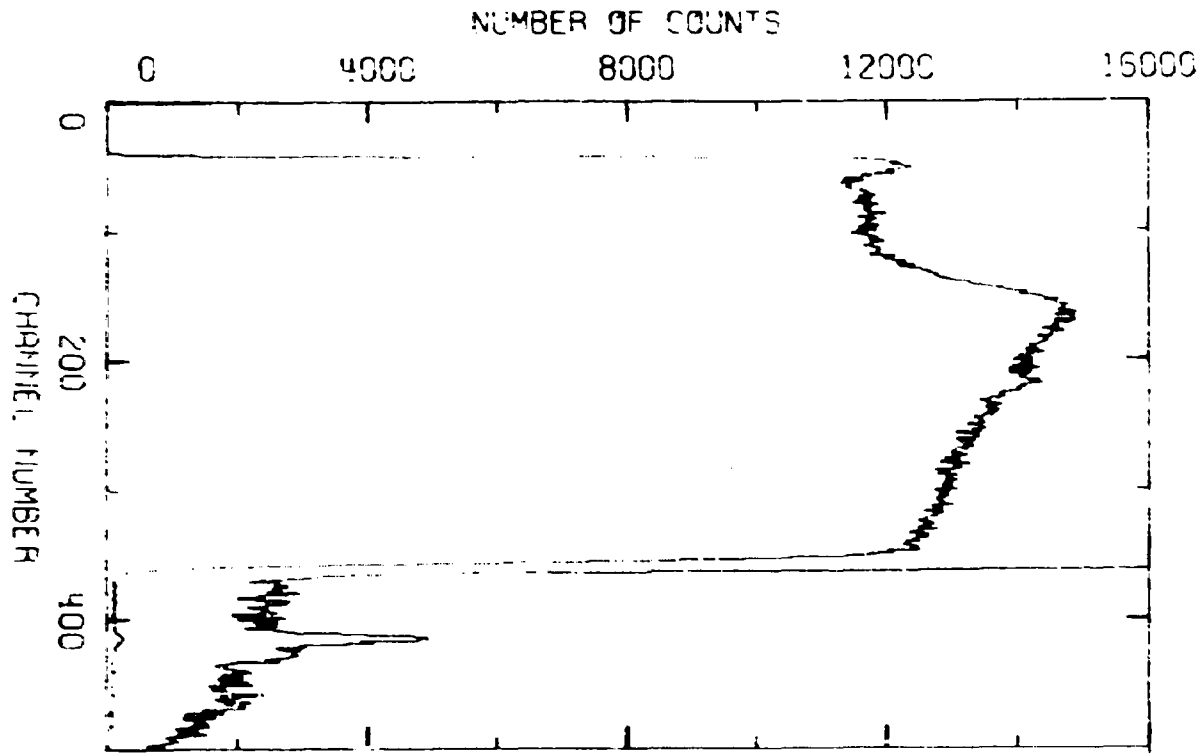

Fig. H5 - Spectrum of 3.0-MeV α-particles elastically scattered from Al foil with a 0.1 μ gm/cm^2 of Li on surface. The righthand portion has been multiplied by 20 and replotted to show the peaks from ^{35}Cl and ^{37}Cl.

I. X-rays Produced by Positive Ion Bombardment (D.J. Nagel,* P. Burkhalter,* A.R. Knudson, and K.L. Dunning)

A series of measurements on the x-radiation produced by positive ion bombardment is being planned. Protons, alpha particles, and a variety of heavier ions will be used to bombard various solid targets. Areas of interest include spectral data, cross sections, atomic structure studies, ionization mechanisms, and analysis of surfaces. The use of this technique for the analysis of surfaces (and regions of the order 100 μm below the surfaces) shows great promise.

The data acquisition system based on the SEL 840A computer will be used to store, analyze, and plot the data and, in addition, will be used to control the experiments to a considerable degree. That is, detectors will be moved under computer control and their angular positions recorded; time, charge, photon counts and voltages will be automatically recorded; spectra will be displayed on an oscilloscope; eventually, accelerator parameters will be monitored and adjusted by the computer system.

*X-Ray Optics Branch, NPD

V. VAN DE GRAAFF USER NOTES

A. Applied Optics Branch, Solid State Division (J.A. Blodgett)

In an effort to determine the suitability of using the orientation of M centers in alkali halide crystals as a storage medium for holographic information, it became apparent that it would be necessary to produce a thin layer of these defects. To accomplish this, NaF crystals were irradiated with 1-MeV protons and 5-MeV helium ions using the Van de Graaff accelerator. This produced a concentrated layer of F and M centers approximately 15μ thick on the crystal surface and these were found to provide a dynamic range of 2.0 optical decades. This would be adequate for most purposes concerned with optical information storage, but additional experiments would be required to verify that high quality holograms could be stored and read using this material.

B. Metal Physics Branch, Metallurgy Division (C.M. Williams)

Since 1963, the Metal Physics Branch has had a program for determining the effects of charged particle irradiation upon thin ferromagnetic films. The irradiations use a scanned beam of 2-MeV He^3 particles from the 5-MV Van de Graaff accelerator. The films are of iron-nickel alloy, formed by vacuum evaporation upon a substrate such as glass or quartz. Controls during film preparation may include orienting magnetic fields. During irradiations, parameters such as temperature, magnetic field (by means of a large Helmholtz coil), and total flux may be varied. Often, measurements are alternated with irradiation to determine effects as a function of integrated flux for the same film.

The results of uniaxial anisotropy energy measurements on ^3He irradiated Permalloy films show that K_u for compositions around 50% nickel, where Ni-Fe long-range order is known to occur, is strongly dependent on grain size. By irradiating these films near the critical temperature for order-disorder, in the presence of a magnetic field, the value of K_u was found to be at least a factor of 2 higher in the larger grain size films (grain size [illegible]-4000 angstroms) than in the smaller grain size films ([illegible] angstroms grain size).

VI. PUBLICATIONS AND TECHNICAL TALKS

A. Van de Graaff Branch

1. Publications

L. Cohen G. H. Herling[1]	"$^{9}Be(t,t)^{9}Be$ and $^{9}Be(t,\alpha_0)^{8}Li$ Reactions at 2.10 MeV," Nuclear Physics, A141, No. 3, 595 (1970).
A. R. Knudson F. Young	"The $^{14}N(^{3}He,\alpha)^{13}N$ Reaction," Nuclear Physics, A149, No. 2, 323 (1970).
D. Jones[2] P. R. Malmberg T. H. May C. V. Strain[3]	"Nondestructive Assay of Fissionable Materials," Nucl. Appl. and Technol. 8, No. 1, 79 (1970).
P. R. Malmberg A. L. Snyder[4]	"December 1969 Field Tests with the NRL Large BF_3 Neutron Detector Array (LND)" (U), NRL Memo Report 2125 (S), May 1970.
J. E. Davey[5] T. Pankey[5] P. Malmberg W. Lucke[3]	"Ion-Implantation-Induced Optical Absorption Edge Shifts in GaP," accepted for publication in Applied Physics Letters.
Van de Graaff Staff, Edited by: K. L. Dunning	"NRL Van de Graaff Operation, 1 July - 31 December 1969," NRL Memo Report 2124, April 1970.
J. W. Butler	"On the Lewis-Tolman Lever Paradox," Amer. Jour. of Phys. 38 (1970) 360.

2. Technical Talks

J. Butler E. Wolicki[3] M. Bernett[6]	"Analysis of Metal Surfaces for Residual Grains of Polishing Compound," American Nuclear Society Meeting, Los Angeles, June, 1970. Trans. Amer. Nucl. Soc., Vol. 13, No. 1, 57 (1970).

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[2]Linac Branch, Nuclear Physics Division
[3]Nuclear Physics Division Staff
[4]Nuclear Systems Branch, NPD
[5]Electronics Division
[6]Laboratory for Chemical Physics

A. R. Knudson K. L. Dunning	"Detection of Chlorine by Charged-Particle-Induced Reactions," American Nuclear Society Meeting, Los Angeles, June, 1970. Trans. Amer. Nucl. Soc. Vol. 13, No. 1, 57 (1970).
F. C. Young A. R. Knudson R. O. Mead[1]	"(^{3}He,^{7}Li) Reaction on ^{9}Be," Amer. Phys. Soc. Mtg., Washington, D.C., April, 1969. Bull. Amer. Phys. Soc. Ser. II, Vol. 15, 629 (1970).
C. J. Crannell[1] H. Crannell[2] C. O'Sullivan[2] T. H. May	"Enhancement of Alpha Particle Tracks in Cellulose Nitrate Using Electric Fields," 12th Scintillation and Semiconductor Counter Symposium, Wash., D.C., March, 1970. IEEE Trans. on Nucl. Science, Vol. NS-17, No. 3, June, 1970.

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13. ABSTRACT

This report is the fifth of a series of semiannual summaries on the use of the 5-MV Van de Graaff accelerator and associated instruments. The period 1 January 1970 to 30 June 1970 is covered. A brief statistical summary is presented, a few important developments concerning the maintenance and improvement of apparatus are discussed, and brief accounts of on-going and recently completed research projects are given.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Van de Graaff accelerator						
Ion implantation						
Materials analysis						
Detection of chlorine						
Ion-induced X-rays						
Ferromagnetic films						
M-ceneters						